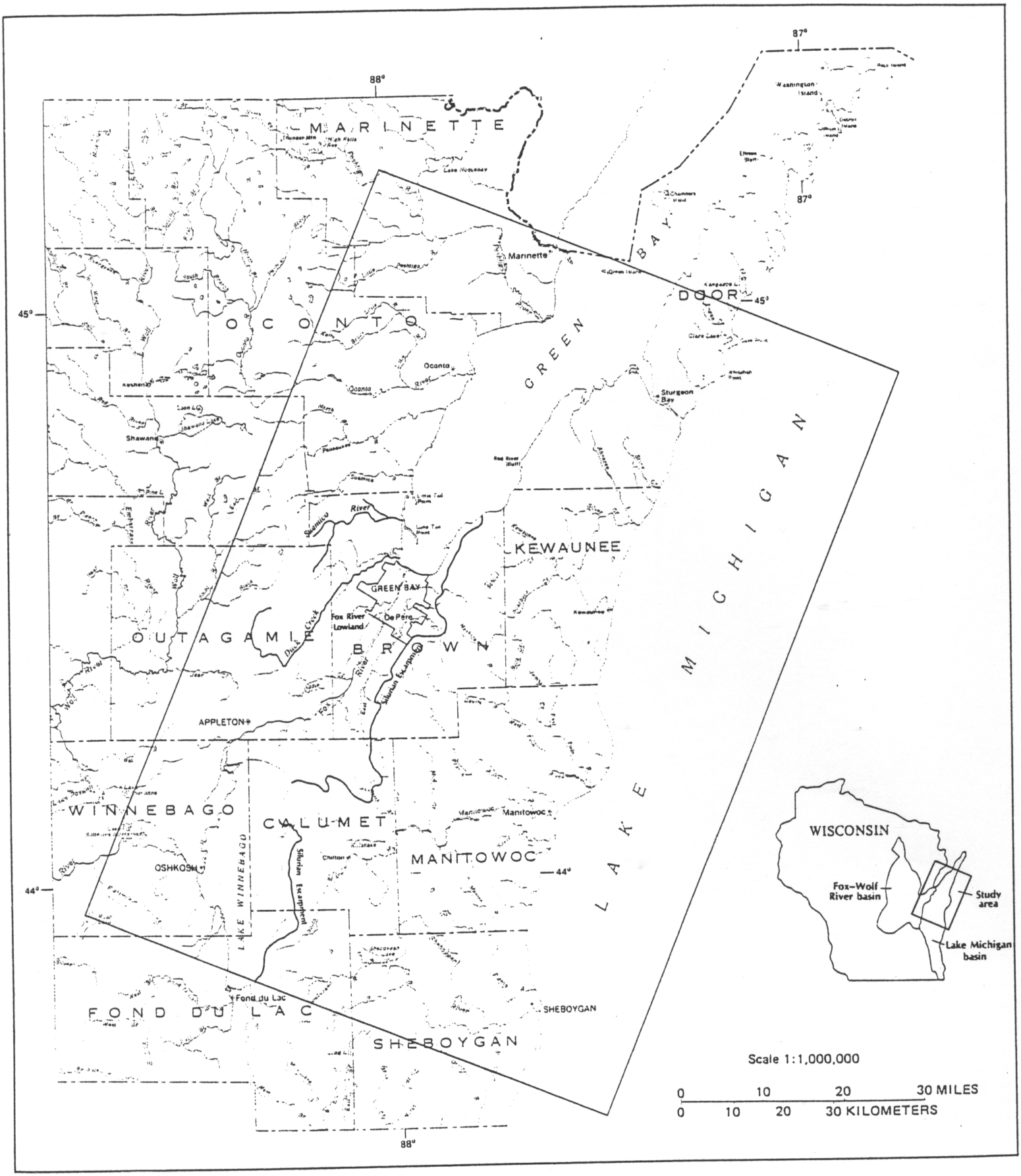
APPENDIX D

STRATIGRAPHIC CROSS-SECTION AND OTHER PERTINENT INFORMATION CONCERNING THE REGIONAL GEOLOGY OF THE AREA (KROHELSKI AND BROWN, 1986)



Base from U.S.G.S.
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Figure 1. Location of the study area.

HYDROGEOLOGY

GEOLOGY

The descriptions of rock units presented in this report are based on drill cuttings obtained from Brown County wells. Lithologies of many of the rock formations are not uniform areally and, in fact, can differ over short distances. The formations include aquifers and confining units. The lithology and areal extent of the rocks and sediments in Brown County are summarized in table 1. The stratigraphy and nomenclature used in this report is that of Mudrey, Brown, and Greenberg (1982).

Bedrock Geology

***By B. A. Brown*[1]**

Brown County is underlain by Paleozoic sedimentary rocks that range in age from Cambrian to Silurian. The rocks rest directly on Precambrian basement rocks that consist predominantly of red granite. The Paleozoic rocks and the Precambrian surface slope to the east beneath Lake Michigan toward the Michigan Basin at about 30 to 40 ft/mi (fig. 2). Erosion has removed the Silurian rocks and the Maquoketa Formation in the western part of the county (fig. 3). The total thickness of the Paleozoic rocks ranges from 200 ft in the west to about 1,600 ft in eastern Brown County.

Cambrian System

The basal unit of the Cambrian is the Elk Mound Group, which overlies the Precambrian. The group normally consists of, in ascending order, the Mount Simon, Eau Claire, and Wonewoc Formations. The group name is used because the Eau Claire Formation cannot be identified in Brown County, and the sandstones of the Mount Simon and Wonewoc Formations commonly cannot be distinguished from one another.

In areas where these formations are distinguishable, the Mount Simon Formation consists of poorly cemented, subangular, fine to very fine-grained sandstone, which may locally be silty. The Wonewoc Formation consists of poorly cemented, subrounded medium to coarse-grained sandstone.

The Tunnel City Group overlies the Elk Mound Group and includes the Lone Rock and the Mazomanie Formations. The Mazomanie Formation is a fine to medium-grained, feldspathic sandstone. The Lone Rock Formation ranges from a dolomitic, feldspathic, glauconitic siltstone or sandstone to a sandy glauconitic dolomite. The Mazomanie and Lone Rock Formations are laterally equivalent facies and either or both facies may be present in the same well. Where fine-grained dolomite of the Lone Rock facies is present, it is difficult to identify the upper contact of the Tunnel City Group because of the similarity of these rocks to the overlying St. Lawrence Formation.

The Trempealeau Group, which consists of the St. Lawrence Formation and Jordan Formations, overlies the Tunnel City Group. The St. Lawrence Formation is a silty, shaly dolomite that commonly contains glauconite. The Jordan Formation can locally be subdivided into the Van Oser and Coon Valley Members. The Van Oser Member consists of very fine to very coarse sandstone, commonly dolomitic that contains minor glauconite. The Coon Valley Member consists of dolomite that contains variable amounts of sand, shale, and minor glauconite. This member is difficult to identify from drill cuttings. The Trempleau Group can be subdivided only where the Van Oser Member is present.

Ordovician System

The Prairie du Chien Group consists of the Oneota and Shakopee Formations. The Shakopee Formation is further subdivided into the lower New Richmond Member and upper Willow River Member. The Oneota Formation and the Willow River Member are very similar, consisting of massive dolomite with minor limestone and oolitic chert. The New Richmond Member consists of sandstone, shaly sandstone, or dolomitic sandstone. The Prairie du Chien Group can be subdivided only in wells where the New Richmond is present. Erosion that occurred prior to deposition of the overlying Ancell Group has removed the Prairie du Chien Group rocks in some areas of Brown County.

The Ancell Group consists of the St. Peter and Glenwood Formation. The St. Peter Formation is composed of two members—the lower Readstown Member, which consists of sandy shale with chert layers, and the overlying Tonti Member, which consists of poorly cemented fine to medium-grained sandstone. The overlying Glenwood Formation is a silty sandstone.

The St. Peter Formation varies areally in thickness because of erosion of the Prairie du Chien strata in pre-St. Peter time. The St. Peter reaches a maximum thickness of up to 300 ft under the Fox River Valley in the area of De Pere, but thins rapidly to as little as 40 ft several miles to the east and west.

The Ancell Group is overlain by the Sinnipee Group, which includes the Platteville, Decorah, and Galena Formations. The Platteville and Galena Formations consist of dolomite that contains fossil fragments and shaly layers. The Galena is distinguished from the Platteville by its chert content. The Decorah Formation is predominantly shale. The Sinnipee Group can be subdivided with certainly only in wells where shale of the Decorah Formation is present between the underlying Platteville and overlying Galena Formations.

The Maquoketa Formation overlies the Sinnipee Group in the area to the east of the Fox River. This formation consists of the Scales Member (a dolomitic shale), which is overlain by the Fort Atkinson Member (a fossiliferous dolomite), which is overlain by the Brainerd Member (another dolomitic shale). The Maquoketa Formation can be subdivided only in northeastern Brown County, where the Fort Atkinson Member is present.

Silurian System

The rocks of the Silurian System are not subdivided in the subsurface of Brown County. These rocks underlie the area east of the Fox River lowland, and consist of massive

[1] Wisconsin Geological and Natural History Survey.

dolomite containing variable amounts of fossil fragments, calcite and gypsum crystals, pyrite, and minor limestone.

Pleistocene

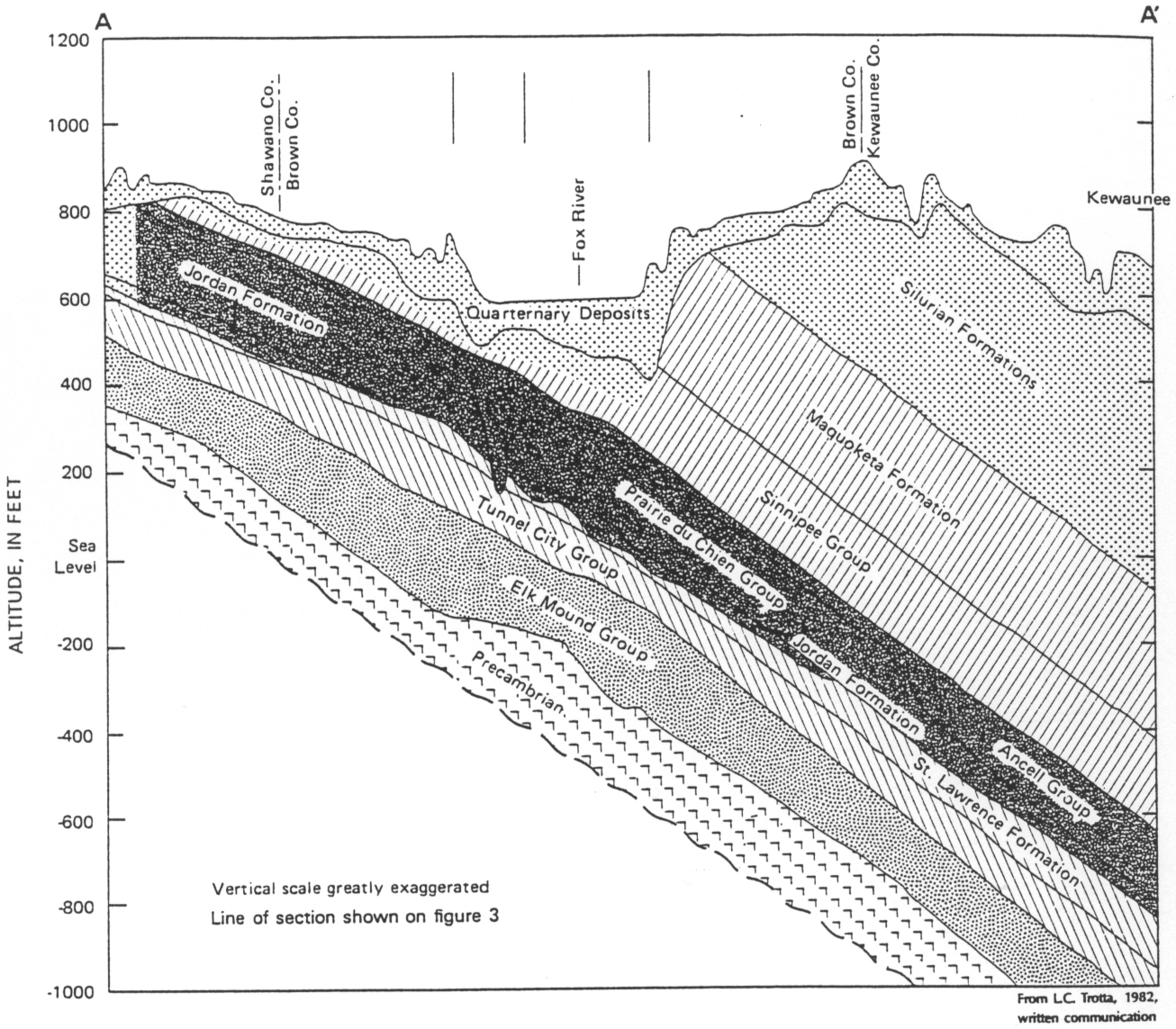
Pleistocene deposits overlie the Paleozoic rock in Brown County and are more than 50 ft thick in most places and more than 200 ft thick in the southwestern part of the county (fig. 4). These unconsolidated deposits were mapped by Need (1983) and the following description is based on that work.

Several glacial episodes are recorded in Brown County Pleistocene deposits. Seven tills and their associated fluvial

Table 1. Stratigraphy of Brown County

Age	Rock unit	Lithology	Areal extent
Quaternary Pleistocene	Kewaunee Formation Horicon Formation	Fluvial, lacustrine, wind blown, and peat deposits, and till	Predominantly fine-grained till except for Fox River valley and area adjacent to west side of Green Bay where lacustrine silt and clay are common. Sand and gravel deposits of small areal extent are present throughout the county.
Silurian	Undifferentiated	Dolomite with varying amounts of fossil fragments, gypsum crystals, pyrite, and limestone.	Subcrops east of the Silurian escarpment.
Ordovician	Maquoketa Formation Brainerd Member Fort Atkinson Member Scales Member	Predominantly dolomitic shale. The Fort Atkinson Member is fossiliferous dolomite.	Subcrops in a band generally less than 3 mi wide west of the Silurian escarpment. Present directly beneath the Silurian dolomite.
	Sinnipee Group Galena Formation Decorah Formation Platteville Formation	Galena and Platteville Formations are dolomite. The Decorah Formation is shale.	Subcrops just east of the Fox River and throughout the county west of the river.
	Ancell Group Glenwood Formation St. Peter Formation Tonti Member Readstown Member	The Glenwood Formation is a silty sandstone, the Tonti Member is a fine- to medium-grained sandstone and the Readstown Member is a sandy shale.	Commonly present in the Fox River valley but thins rapidly east and west of the valley.
	Prairie du Chien Group Shakopee Formation Willow River Member New Richmond Member Oneota Formation	The Prairie du Chien Group is generally dolomite with varying amounts of oolitic chert. The group can be subdivided only when the New Richmond Member, a sandstone, shaly sandstone, or dolomitic sandstone, is present.	Thin or absent where the St. Peter Sandstone is thick (Fox River valley).
Cambrian	Trempealeau Group Jordan Formation St. Lawrence Formation	The Jordan Formation is a fine- to medium-grained sandstone. The St. Lawrence Formation is a silty glauconitic dolomite.	Present throughout the county.
	Tunnel City Group Mazomanie Formation Lone Rock Formation	The Mazomanie Formation is a fine- to medium-grained sandstone. The Lone Rock Formation is a silty sandstone to a sandy dolomite.	Present throughout the county.
	Elk Mound Group Wonowoc Formation Eau Claire Formation Mount Simon Formation	The members of the Elk Mound Group are usually not differentiated. Where distinguishable the units generally present are a very fine to fine-grained sandstone and a medium- to coarse-grained sandstone.	Present throughout the county.
Precambrian		Red granite	Basement rock throughout the county.

1/ The stratigraphic nomenclature used in this report is that of the Wisconsin Geological and Natural History Survey and does not necessarily follow usage of the U.S. Geological Survey.



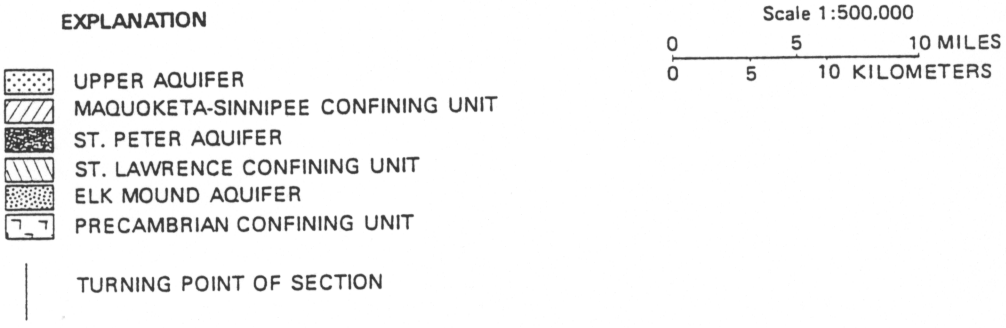


Figure 2. Hydrogeologic section through study area.

and lacustrine deposits are present in the Brown County area. Tills were deposited by the Green Bay and Lake Michigan Lobes of the ice sheet. Fluvial sand and gravel were deposited by glacial meltwater from the lobes. Lacustrine sediment, generally fine grained (silt or clay), was deposited in two ice dammed lakes—Nipissing Lake and Lake Oshkosh. Modern sediments deposited by wind, water, and the accumulation of organic matter are also present in Brown County. Figure 5 shows the areal distribution of groupings of Pleistocene surface deposits in Brown County. The groupings are till, silt and clay, and sand and gravel. Figure 6 is an east-west geologic section through northern Brown

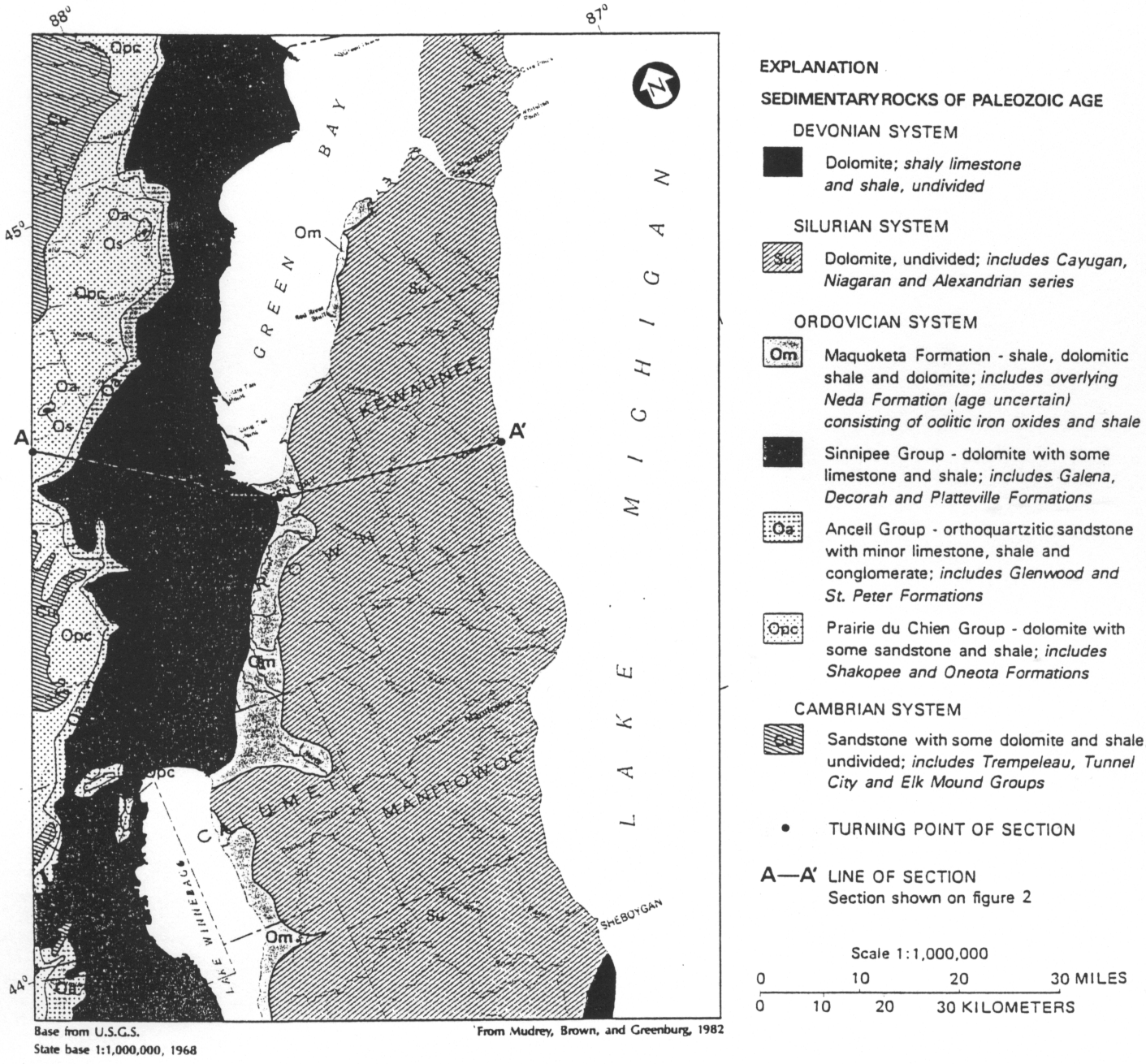


Figure 3. Bedrock geology.

County showing the vertical distribution of Pleistocene deposits.

The following is a brief description of the Pleistocene deposits in order of their relative age from youngest to oldest.

Modern Deposits

1. *Modern stream sediment* is silt loam and silt channel-fill and flood-plain deposits. It is present adjacent to most county streams.
2. *Windblown sand* is well-sorted fine sand in transverse dunes present in northwestern Brown County.
3. *Organic and hillslope sediment in topographic depressions* is loam to silty clay slopewash sediment overlain by peat and muck. It is present in small areas throughout the county.

Kewaunee Formation

1. *Nipissing Lake Plain and Lake Oshkosh Plain sediment* vary from clay to silt loam. This sediment is present at the surface in the Fox River lowland.
2. *Stream sediment in spillways* is gravelly sand, sand, and sandy gravel point-bar and channel-lag deposits in steep-walled channels that drained proglacial Lake Oshkosh. It is present in two locations in eastern Brown County.
3. *Till of the Middle Inlet Member* is reddish brown, calcareous, loam till and is the surface unit in northwestern Brown County. It is present discontinuously in the subsurface in the Fox River lowland near the west side of Green Bay.
4. *Till of the Glenmore Member* is reddish brown, calcareous, silty clay loam till that is the surface unit throughout most of eastern Brown County. It has been identified in the subsurface in the Fox River lowland west of the Fox River.
5. *The Duck Creek Ridge Complex* is sediment of the Middle Inlet and Kirby Lake Members, stream sediment, and clayey lake sediment. It is present in a glacially eroded, elongated ridge near the east side of Duck Creek.
6. *Meltwater-stream sediment exposed by glacial and postglacial erosion* is well-sorted sand exposed along elongated ridges and steep slopes. It is present at the surface and in the subsurface in western and northwestern Brown County.
7. *Till of the Kirby Lake Member* is reddish brown, calcareous, clay loam to silty clay loam till. It is not exposed at the surface but is present in the subsurface throughout northwestern and west-central Brown County.
8. *Till of the Chilton Member* is reddish brown, calcareous, silty clay loam till. It is exposed at the surface in southern Brown County and present in the subsurface in the Fox River lowland south of Green Bay.
9. *Till of the Valders Member* is reddish brown, calcareous, silt loam till and is exposed in southeastern Brown County but is not present to any significant extent in the subsurface.
10. *Clayey offshore sediment exposed by glacial and stream erosion* is silty clay loam, silty clay, and clay that was deposited in proglacial lakes predating the Chilton and Kirby Lake Members. This unit is exposed at the surface in northwestern Brown County and in the subsurface throughout most of the Fox River lowland.
11. *Meltwater stream sediment* is gravelly sand, sand, and sandy gravel with minor amounts of silt loam. It is present at the surface in southern Brown County near the Branch River and is discontinuous in the subsurface in the Fox River lowland.
12. *Till of the Branch River Member* is light reddish brown, calcareous, loam till. It is exposed at the surface in southern Brown County and around the margins of an erosional window of the Wayside till in northeastern Brown County. The Branch River Member is also thought to be present in the subsurface throughout the eastern part of the county.

Horicon Formation

1. *Till of the Wayside Member* is light-grayish brown, calcareous, stony loam till and is exposed at the surface in southern Brown County.
2. *Meltwater-stream sediment* is sand and gravel, discontinuous in the subsurface in eastern Brown County.

AQUIFERS AND CONFINING UNITS

The complex hydrogeologic system in the Brown County area consists of aquifers and confining units. The hydrogeologic system includes an upper aquifer and deep aquifers separated by confining units. Previous studies have defined the "sandstone aquifer" in the Brown County area to include Cambrian and Ordovician Formations older than the Maquoketa Formation (Donohue, 1976; Drescher, 1953; Knowles, 1964). Although it was recognized in previous studies that the "sandstone aquifer" did not have uniform hydraulic properties and was not a single aquifer, it was considered a single aquifer because hydraulic data on individual formations were not available. Most high-capacity wells in Brown County are drilled through and open to most of the formations of the "sandstone aquifer".

The division of aquifers and confining units in this report is based on the composition and hydraulic information of the rock groups or formations present in the Brown County area. Figure 2 shows rock groups and formations present in the Brown County area and the aquifers and confining units defined in this report. The general range in thickness of the aquifers and confining units can be seen in figures 7 and 15a. Table 2 lists hydraulic parameters for the aquifers and confining units. The locations of pump tests and